Aerostar's Mark West:

Weather and environment affect balloon performance

Keynotes New Hampshire Safety Seminar

By James E. Ellis

Aerostar President Mark West recently offered insights into the effects of weather and environment effects on hot air balloon performance. West was the keynote speaker at the Iron Butt Safety Seminar in Hillsboro, New Hampshire.

His remarks covered lift, fuel consumption, aerodynamic effects and drag, and solar radiation and UV effects.

Lift. West noted that lift is equal to the volume of the balloon multiplied by the difference in air density inside and outside the balloon. But the air density is not constant inside the balloon, he said. There is a gradient from the hottest low-density air in the top down to the air at the throat being nearly equal to the outside air.

The hottest spot in the balloon is about one and one-half feet below the center of the top cap. West had a surprise for those who think that the temperature sensor is at the hottest part of the balloon: the sensors in Aerostar balloons are designed to be at a spot with average high temperatures, not maximum temperatures. High humidity actually has less of an impact on lift and temperatures than one might expect: Going from 0% to 100% humidity at 85 degrees F results in a density altitude increase of 525 feet, which equates to a 3.5 degree increase in envelope temperature or a 1.9% loss of lift for a 90,000 cu. ft. balloon.

Extended burns cause the top of a balloon to fill with CO2 and water vapor, resulting in oxygen-starved poor burning known as "whooshing out". The solution: vent

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Fuel consumption. West noted that wind blowing across the surface of the envelope will cause the greatest loss of temperature. This could be from climbs or descents; crossing shears; or tethering in winds. If one is trying to conserve fuel, the best strategy is to minimize climbs and descents to minimize the relative wind and resulting heat loss. He cautioned commercial balloonists who do tethers in winds to be aware that winds over the balloon can double normal fuel consumption, meaning they could run out of propane much sooner than they expect.

A lesser heat loss is purge loss, which results when air is forced out of the bottom of a balloon as it expands during a burn. Purge losses are related to the Zero Pressure level, which is the location where the pressure in the balloon equals the pressure outside the balloon. It is effectively where the lifting part of the balloon ends. In a normally loaded balloon, this point is about one-third of the way up the balloon, with the top two-thirds lifting. In a heavily loaded balloon, the whole balloon is required to provide lift and the Zero Pressure level drops down to near the mouth, meaning purge losses will be greater in a heavily loaded balloon.

Not surprisingly, West said, fuel consumption is highest when the difference between the ambient air and the balloon temperature is the highest. The highest fuel consumption will be in a heavily loaded balloon on a hot summer day. Normal fuel consumption for a medium size balloon is about 16 gph. West cautioned that fuel consumption is not linear: heavily loaded balloons in high temperatures will use considerably more fuel.

In the past West was criticized for initiating mandatory porosity checks on Aerostar balloons. West said that he learned first hand how serious porosity effects can be when he flew an old balloon with 470 hours on it (back when normal balloon life for nylon balloons was around 300 hours). He was shocked to find that the balloon burned 40 gallons of propane in 40 minutes! He noted that porosity effects are concentrated in the top half to two-thirds of the balloon that does most of the lifting.

West discussed the effects of humidity on burner performance. He said that propane is a very clean burning fuel, producing water vapor and carbon dioxide as combustion byproducts. Amazingly, burning one gallon of propane generates two gallons of water! With extended burns, the top of the balloon fills with CO2 and water vapor. In a heavily loaded balloon with the Zero Pressure level near the mouth, the CO2 and water vapor can extend down to near the mouth, especially with extended burns. This can result in oxygen-starved poor burning, which West called to as "whooshing out". West said one answer to poor burner performance under these circumstances is to vent. The loss of heat from venting will be much less than the heat that can now be added with better burner performance.

Relative to skirts versus scoops, West said that skirts improve fuel consumption, but that scoops are better at getting rid of combustion byproducts near the mouth.

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Aerodynamic Effects and Drag. West said that wind blowing against a balloon can cause a low-pressure zone on the downwind side. Showing the equation to calculate drag from wind blowing over a balloon, West noted that the velocity term is squared for drag effects, meaning that drag effects increase exponentially and not linearly with an increase in wind velocity over or against the balloon. One result of this is why a balloon reaches a terminal velocity in a burner-off descent. The exponential increase in drag eventually offsets the gravitational effects and the balloon vertical speed no longer increases.

Another application is in determining forces on tether lines or in using droplines to stop moving balloons. For a 77,500 cu. ft. AX-7, winds and resulting forces are as follows: 3 mph: 21 lbs.; 6 mph: 109 lbs.; 9 mph: 246 lbs.; 12 mph: 437 lbs.; and 15 mph; 683 lbs. (One clear message: don't even think about having one or two crew people grab a drop-line to stop a balloon going more than 10 mph! It also explains why a gust of wind in excess of 20 mph can result in a balloon dragging a small pickup truck 15 or 20 feet!)

West described some experiences in testing, instructing in, or just flying Aerostar balloons. In terminal descents, he said, a balloon will slow down, speed up, and slow down again. He attributes this to an effect that when the balloon slows down, the heat loss becomes less, so the balloon cools less when it slows down. He believes that the effect of air compressing during a terminal descent actually puts some small amount of heat back in the balloon.

High-speed ascents and descents in cylindrical (beer or soda can) balloons cause baskets to pitch or swing first one way and then the other repeatedly, finally settling into a corkscrew-like climbing or descending motion.

Shortly after he joined Raven, he was involved in testing a 211,000 cu. ft. balloon. The balloon had a negative slant on the suspension cables, and the throat closed in a descent. Fortunately, it popped back open before West would have had to burn through it. Aerostar balloons now have a positive slant on the suspension cables (the attach points on the burner frame are farther out than the diameter of the mouth of the balloon) to induce the mouth to stay open.

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Solar radiation and UV effects. West said that on June 20, the day with the maximum amount of daylight, solar radiation and UV effects at one hour after sunrise are only one-fifth those at noon. On December 20, the shortest solar day of the year when sun angles are at their lowest, the solar radiation and UV effects at noon are approximately equal to those at one hour before sunrise on June 20. And one hour after sunrise on December 20, the solar and UV effects are only one-fifth of those at noon on December 20. West said that with modern fabrics there isn't much difference in UV effects on different colors, and that UV degradation is of course worst in the summer months when solar radiation is strongest.

More than 106 balloon pilots and crew attended the 24th Annual Ironbutt Balloon Safety Seminar held on February 12, 2005 in Hillsboro, New Hampshire. Organizer of the annual event is Mary Ann Lappies.